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Patent Application

S/PR/TS

10/539843

SOUND PROJECTORBACKGROUND OF THE INVENTIONField of the invention

[0002] The invention relates to a directional loudspeaker and to a method which is suitable for operating such a directional loudspeaker in accordance with the precharacterizing parts of patent claims 1 and 13.

Related Art of the Invention

[0003] Conventional systems in which the audio signal is radiated as an oscillation of air directly via single loudspeakers or else a loudspeaker array are able to achieve only relatively limited focusing of the radiated sound. By contrast, a novel method sends the audio signal not directly but rather as an alteration in the amplitude (amplitude modulation, AM) of a carrier oscillation at very high frequency (ultrasound). The underlying physical phenomenon of acoustic perception of sounds as a sequence of nonlinear properties of the air has already been recognized and examined by the physicists Helmholtz in the 19th century. The application of the physical principles for building an ultrasound/audio loudspeaker are described by Yoneyama, Fujimoto, Kawamo and Sasabe ('The audio spotlight: An application of non-linear interaction of sound waves to a new type of loud-speaker design', Journal of the Acoustic Society of America, 1983, pages 1532-1536).

[0004] The sound field from "parametric loudspeakers" first of all comprises only the inaudible ultrasound signal modulated with the useful signal, the audio signal. The high sound

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pressure of the inaudible ultrasound alters the medium of air, i.e. it becomes nonlinear. This nonlinearity results in demodulation of the audio signal which is now becoming audible. In the direction of propagation of the ultrasound, the audio sound produced is added in the correct phase.

[0005] A megaphone, which utilizes the directivity of a parametric loudspeaker system, is described in US 6 359 990 B1. In this context, the audible signal spoken into a microphone is transmitted directionally using an annular arrangement of ultrasound signal generators.

[0006] Options for influencing the direction of radiation of a parametric loudspeaker system are also described in the specification US 6 229 899 B1. This proposes influencing the direction of the narrowly focused ultrasound signal by either using the special electronic actuation means (electronic beam forming) or else diverting the signal using mechanical mirror arrangements. An appropriate mechanical mirror arrangement is known from the patent US 4 791 430 A1, for example, which discloses what is known as an ultrasound antenna. An arrangement comprising a first and a second reflector is used to divert a focused ultrasound signal and to manipulate the shape of its cross section.

[0007] The specification WO 99/44757 A1 discloses an apparatus for specifically radiating ultrasound signals. Besides a combined ultrasound transmitter/receiver, the apparatus comprises a rotatably mounted reflector which can be used, among other things, to deflect the ray coming from the ultrasound

source into different spatial directions. In this context, the ultrasound transmitter/receiver and the reflector are mounted separately on a common support. Since the total arrangement is not surrounded by a housing, there is the risk of the reflective face becoming soiled and of moisture penetrating the transmission/reception unit, particularly when the arrangement is used in the open air.

#### **SUMMARY OF THE INVENTION**

**[0008]** It is an object of the invention to find an ultrasound reflector arrangement which can be well protected against soiling and penetrating moisture.

**[0009]** The invention is achieved by a directional loudspeaker and a method for operating a directional loudspeaker having the features of patent claims 1 and 13. Advantageous refinements and developments of the invention are described by the subclaims.

**[00010]** The novel directional loudspeaker comprises a sound source for producing highly directional sound which is formed by at least one ultrasound loudspeaker. There is also a pivotable reflector for deflecting the directional sound. Inventively, the reflector is now designed such that it can be pivoted such that its serves as mechanical protection for the directional loudspeaker's sound source. This protection is particularly against environmental influences such as soiling and moisture. In particularly advantageous fashion, the reflector thus essentially has two different orientations and functions. First, it serves to deflect the energy coming from the directional loudspeaker's sound source into a prescribable, desired

direction through suitable orientation, and secondly the reflector can be folded over the sound source, so that a type of protective casing is produced which protects the ultrasound loudspeakers forming the sound source against mechanical and environmental influences.

**Brief Description of the Drawings**

[00011] The invention and advantageous refinements thereof are explained in detail below with reference to figures.

[00012] Figure 1 shows an example of a system comprising the array baseplate and the foldable reflector.

[00013] Figure 2 shows a possible installation variant (overhead) for the directional loudspeaker.

[00014] Figure 3 shows a variant which comprises a second hinge for tilting the base area.

[00015] Figure 4 shows the plan view of an exemplary arrangement of ultrasound loudspeakers.

[00016] Figure 5 shows the side view of the basic arrangement of reflector and transducer array.

[00017] Figure 6 shows an example of an arrangement in which the reflector has an aperture angle of 60° relative to the base area.

[00018] Figure 7 shows an example with the aperture angle 40°.

[00019] Figure 8 shows an arrangement in which the total system is also pivoted in addition to the reflector.

[00020] Figure 9 shows an exemplary refinement of the directional loudspeaker which allows optimum orientation for a listener.

[00021] Figure 10 shows a further exemplary refinement of the directional loudspeaker which allows optimum orientation.

#### Detailed Description of the Invention

[00022] In particularly profitable fashion, the directional loudspeaker's sound source is installed in a housing which can be sealed with the correct fit by the reflector. To this end, the reflector is particularly advantageously connected to the housing by a moving connection, which results in a type of can in which the reflector forms the lid and which can be opened and closed by changing the orientation of the reflector. In this case, the choice of moving connection is essentially dependent on the demands on the desired degree of movement for the reflector. It is thus conceivable to use a simple hinge, or else, particularly to increase the degrees of movement for the reflector, to resort to ball-and-socket joints, universal joints or cardan joints.

[00023] In particularly profitable fashion, the housing in which the sound source is installed has an essentially circular cross section. This makes it possible, by way of example, to mount the pivot joint on a raceway which is seated on the housing and

which can be used to rotate the reflector along the top edge of the reflector.

[00024] The orientation of the directional loudspeaker can be set particularly advantageously if the housing itself is not mounted solidly on a support but rather is connected to it by means of a joint. This allows the spatial area to which sound can be sent directly by means of the directional loudspeaker to be extended significantly, since it becomes possible, if the orientation of the reflector with respect to the sound source remains the same, to pivot the entire arrangement comprising the reflector and the sound source. Accordingly, the inventive directional loudspeaker can be implemented particularly profitably by using a housing which comprises an outer housing and an inner housing. In this case, the directional loudspeaker's sound source is situated in the inner housing, which is connected to the reflector directly by means of a moving connection. In this context, the inner housing is advantageously mounted so that it can tilt and/or pivot with respect to the outer housing, which means that, in line with the description illustrated above, a significant extension to the surrounding area which can receive sound directly is obtained, while at the same time the outer housing protects the combined pivot arrangement against mechanical and environmental influences.

[00025] Figure 1 shows an example of a system comprising the array baseplate (10) and the foldable reflector (11). In this context, the reflector (11) is mounted on the housing containing the sound source via a joint (12) so that it can move on a

raceway (13). Such an advantageous arrangement is particularly suitable for installation on a surface, such as in a roof lining (20) in a vehicle, in line with figure 2. In particularly profitable fashion, the housing of the directional loudspeaker is inset into this surface. This means that the directional loudspeaker can remain "invisible" at first. To put it into operation, the reflector is opened and is preset in the range around 45°, for example. The precise lateral orientation is obtained by rotation on the raceway (13), and the height orientation is obtained through the aperture angle in the range around 45°. Whereas the joint (12) between the raceway or housing and the reflector (11) allows the reflector (11) to be pivoted essentially vertically, the raceway arranged so as to be able to move on the housing allows the reflector to be moved horizontally, rotating on a round base area.

[00026] If a fixed aperture angle of 45° is sufficient, the second hinge (14, 30) for tilting the base area is not required and the individual elements can be installed either at right angles or with an appropriate inclination so as to focus. If a small range, e.g. of +10°, of the aperture angle around 45° is required, then the focusing arrangement of the ultrasound loudspeakers forming the sound source is recommended. If a large range is required for the aperture angle, then the second hinge (14, 30) is advantageous for tilting the base area, in line with figure 3.

[00027] Other applications are for transmitting sound in larger spaces and likewise in the open air outside of rooms and buildings. Advantageously, the system may be designed as a

mobile unit. In the sealed state, the system is protected mechanically and against the influences of weathering by the reflector and a base unit. During operation, the base unit serves as a support.

[00028] Figure 4 shows a plan view of an example of an arrangement of 25 ultrasound loudspeakers which together form the sound source of the directional loudspeaker. The 25 individual elements (40) in the form of ultrasound loudspeakers are arranged in a square,  $5 \times 5$ , in a round base area. In this context, the individual elements (40) may be in the form of small cylinders, for example, with the sound emergence openings at the top end thereof, said cylinders being installed in a standing position in a common base area. Such an arrangement results in the elements having a direction of radiation at right angles to the base area.

[00029] Figure 5 shows a side view of the basic arrangement of reflector (50) and transducer array. To simplify matters, this figure shows only a single transducer in the array. The reflector is mounted on one side of the housing wall (51). The mounting used between the reflector (50) and the housing wall (51) is a hinge (52) or other joint, for example. If the reflector is arranged, as shown by way of example, at an angle of  $45^\circ$  relative to the array base area, then the reflected sound propagates parallel to the base area (53) of the array of sound transducers.

[00030] The angle of  $45^\circ$  is optimum in the sense that the reflector area (54) reflects the sound from the array completely

(if we assume the highly focused radiation at right angles to the array base area). An angle of greater than 45° requires a larger reflector, and an angle of less than 45° results in partial coverage of the reflection by the base area.

[00031] If the elements in the base area are installed at an appropriate angle such that the radiation is focused, the angle of the reflector can be moved in a wider range. To simplify matters, it will be assumed here that the angle of installation of the elements in the base area is chosen such that a common focal point is obtained. The outer elements then have a greater degree of inclination than the inner ones, and the element in the center is again installed at right angles.

[00032] After the focal point, the sound is defocused and hence the directivity is also widened.

[00033] Figure 6 shows an example of an arrangement in which the reflector (60) is at an aperture angle of 60° relative to the base area. The focal point (61) is situated after the reflection. The angle of installation of an outer element is shown with a value of -70° by way of example. If the focal point (61) were actually situated before the reflection, then the scatter of the sound field would turn out to be even greater. The choice of a focusing angle of installation for the elements in the base area thus permits an optimum aperture angle, which is variable within a certain range, around the value 45° without the drawback that the reflector would need to be enlarged or a portion of the reflection is covered. For an aperture angle of 60°, there is, regardless of focus, a resultant mean radiation

angle:  $2*(60^\circ - 45^\circ) = 30^\circ$ .

[00034] The drawback of the focusing arrangement is defocusing (scatter). If the listener is in the direct proximity of the arrangement in the sound ray, for example, then a certain amount of scatter is entirely tolerable, since the listener himself again acts as a reflector.

[00035] The choices of aperture angle and installation angle for focusing are dependent on one another in that with a large aperture angle it is also necessary to use a large inclination (installation angle) if the reflector size is not intended to be increased.

[00036] Figure 7 shows an example with the aperture angle  $40^\circ$  and the resultant mean radiation angle:  $2*(45^\circ - 40^\circ) = -10^\circ$ .

[00037] The choice of aperture angle, below  $45^\circ$ , and the installation angle of the outer elements in the base area is not totally free, since the reflection may be covered by the base area in this case or no further reflection may take place. In this instance, the exact geometric illustration will be dispensed with. By way of example, the magnitudes obtained as suitable angle of inclination for the outer elements are:  $80^\circ$ ,  $70^\circ$  and  $60^\circ$  for the respective aperture angle of  $40^\circ$ ,  $35^\circ$  and  $30^\circ$ .

[00038] If the listener is at a greater distance from the array, the focusing radiation no longer makes sense because the defocusing losses a large portion of the directivity. It is more advantageous to tilt the basic system as shown in the

illustration in figure 8 and to maintain the optimum aperture angle of 45°.

[00039] By way of example, a plurality of single transducers, i.e. an array system, have been used for the transducer system in the base area. Instead of the individual transducers, the ultrasound transmitter may comprise just one transducer. Ordinary transducers radiate the sound with a high level of directivity in one direction, the sound ray widening somewhat with distance. On the basis of the prior art, an individual transducer may also be designed to have a focusing effect, so that it is of no significance to the total system described whether a single transducer or a plurality of transducers are used.

[00040] The high level of directivity of the system requires orientation to the listener. A simple means of assistance is indicated by way of example in figure 9. In this context, the center of the directional loudspeaker's base area contains an element (90) which radiates a focused beam of light in the direction of the sound propagation. The impingement of the point of light allows the destination, the point at which sound is desired, to be set. In this case, the setting would be made manually. Advantageously, the element (90) is a laser, which emits a focused beam of light which can easily be perceived on the illuminated people or objects.

[00041] Automatic setting to the object which is intended to receive the sound could be done, by way of example, by an opto-electronic image evaluation unit which evaluates the reflection

of a laser beam, for example. This image evaluation unit could then provide the control signals for rotating and tilting the system. Instead of complex image evaluation, control by means of an infrared sensor is also possible, said sensor then following the object with the most intense radiated heat.

[00042] A further option is obtained if the object which is intended to receive sound emits a signal, such as a point of light or a radio signal. A receiver connected to a position-finding device can use this signal to determine the location of the object and can orient the reflector system thereto. If the object which is intended to receive sound emits a point of light, for example from a laser, then an appropriate receiver (100), as indicated in figure 10, can be installed directly in the base area of the directional loudspeaker, in order to evaluate the light reflected by the reflector. In this context, the maximum incidence of light is obtained with a system which has the correct acoustic orientation relative to the light source.

[00043] Particularly advantageously, the novel directional loudspeaker can be used to send sound to people in motor vehicles, since its housing is ideal for being integrated in embedded fashion in internal devices of the vehicle. On the other hand, the novel directional loudspeaker affords profitable opportunities for use outside of vehicles or buildings too, particularly on account of the opportunities for protecting the sound transducers against environmental influences. Directional loudspeakers designed in accordance with the invention can be integrated relatively inconspicuously on the roof of vehicles,

for example, and can thus provide sound specifically for the surrounding area of the vehicle in active operation. By way of example, it would thus be possible on a picnic to provide sound specifically for the limited space in the area of the person or picnic spot without bothering the people in the surrounding area.